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Title: Radiation Detection Theory

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STABILIZATION PROGRAM
NNSA NA-84

Radiation Detection Theory

Lesson Objectives

1. Identify **four types** of radiation detectors
2. Explain the **operational theory** of each detector
3. Identify the **types of radiation** each detector detects
4. Identify each detector's **dose rate range**
5. Identify the **advantages and disadvantages** of each detector

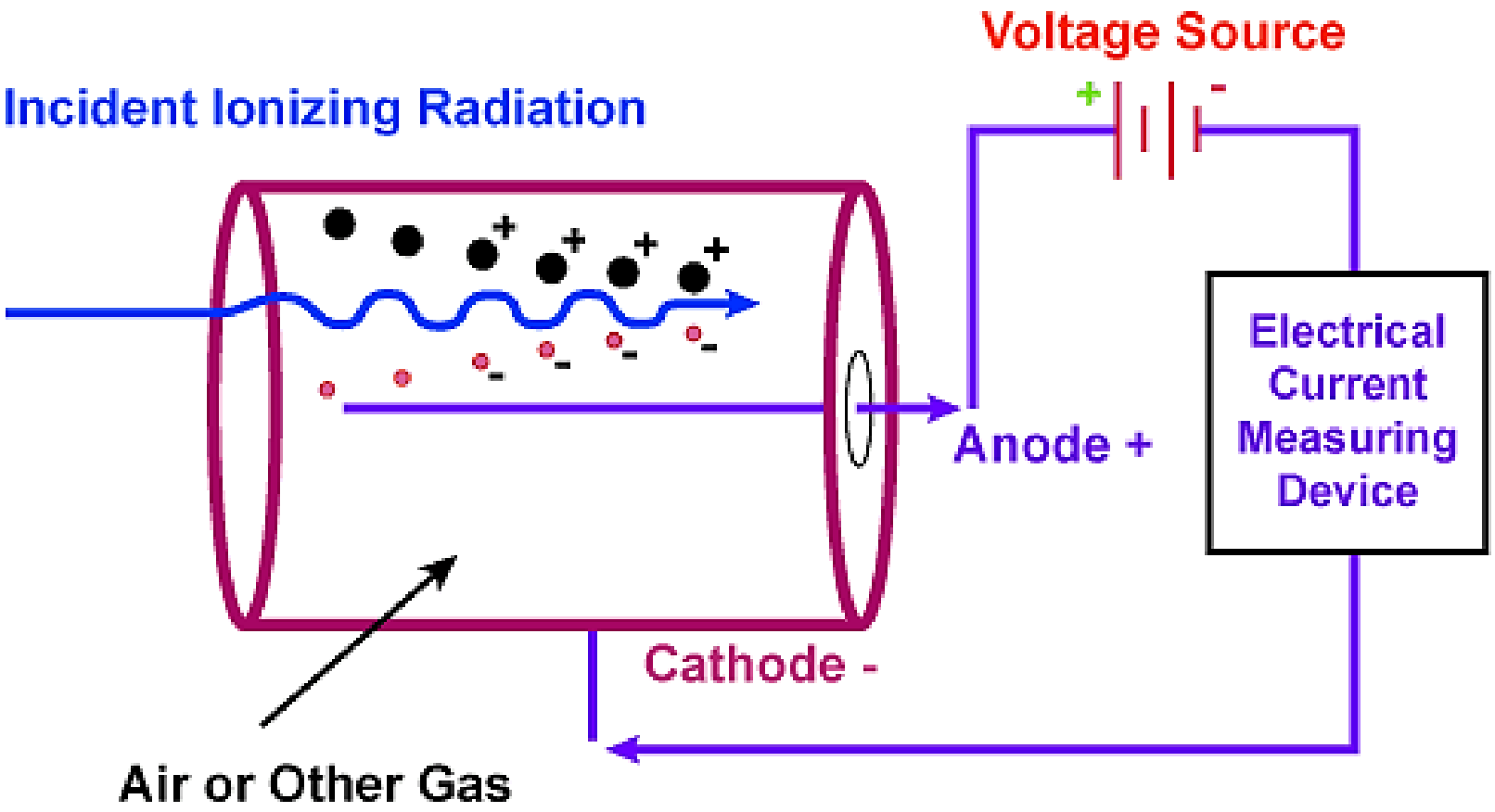
Agenda

- Gas Filled Detectors
- Scintillators
- Semiconductors
- Isotope Identification

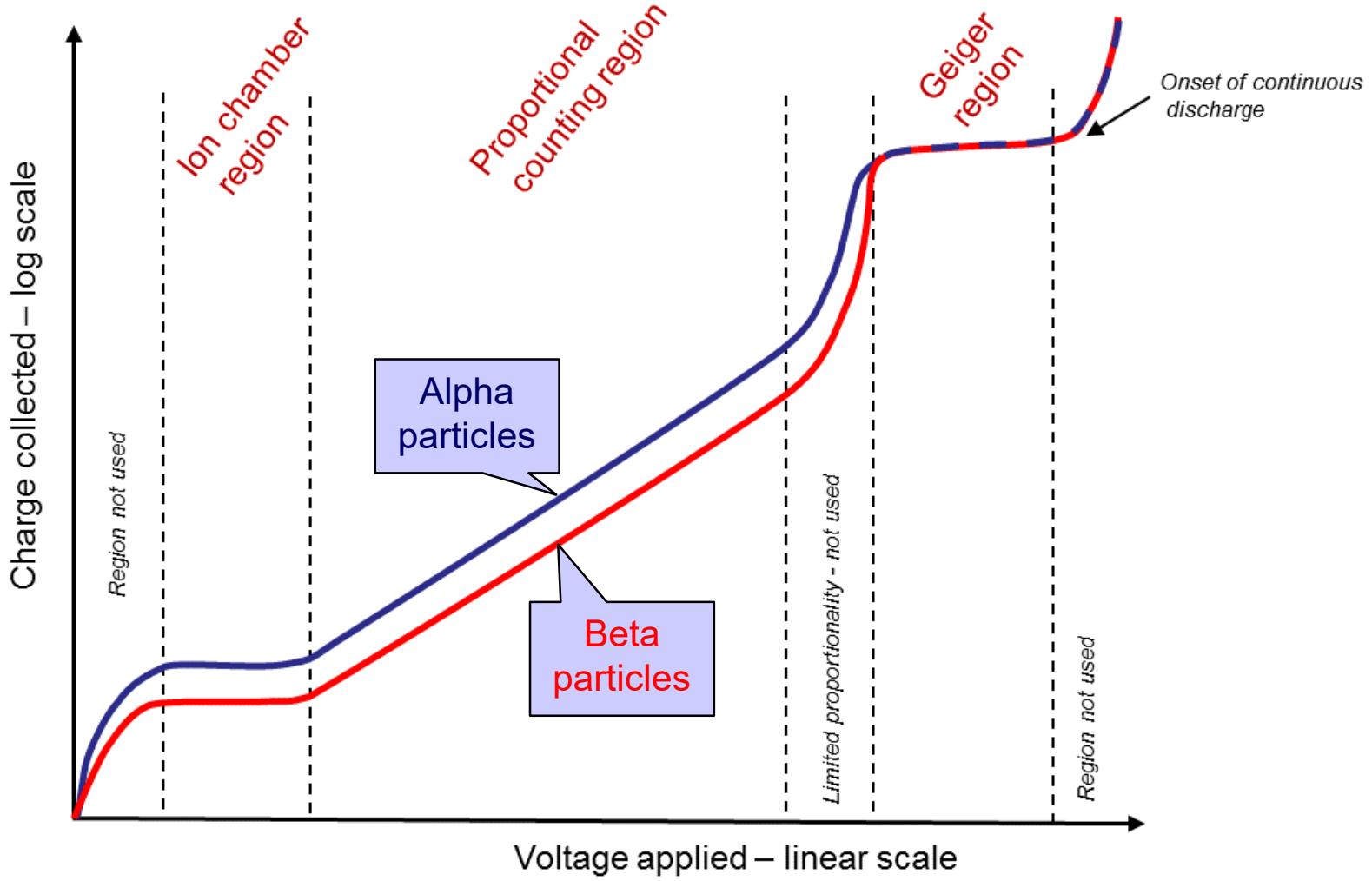
Detector Types

- **Gas Filled**
  - Ion Chamber
  - Proportional Counter (Neutrons!)
  - GM
- **Scintillator**
  - NaI
  - CsI
  - ZnS
- **Semiconductor**
  - HPGe

Gas Filled Detectors



Gas Filled Detectors (cont'd)



Ion Chamber

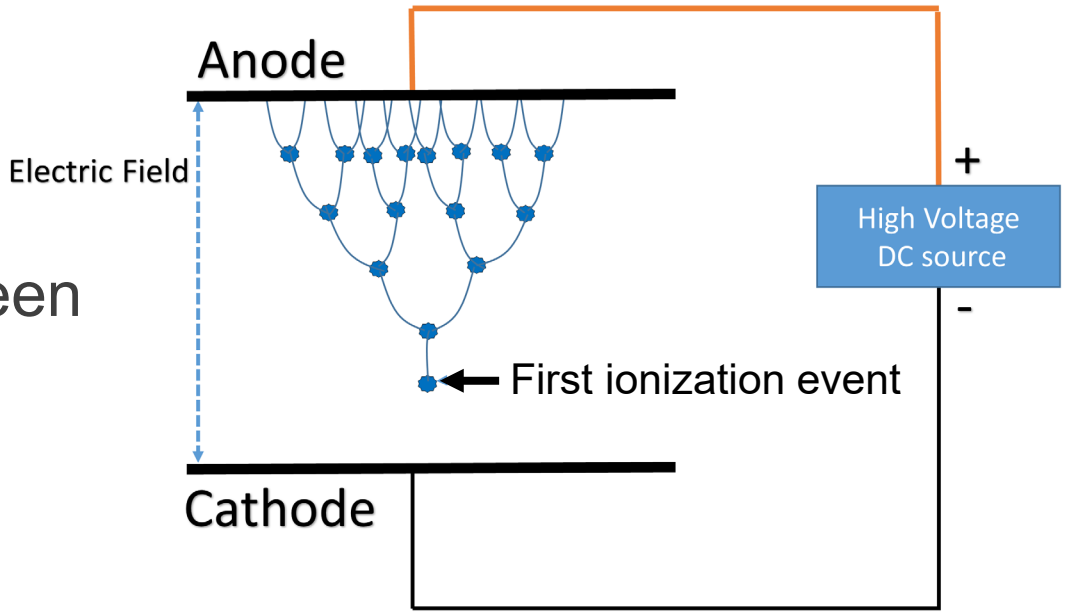
- No gas amplification
- Good accuracy
- Drop in sensitivity below 50-100 keV photons

Fluke 451B

- **Non-pressurized**
- **Dose rate range: 0-500 mSv/hr**
- **Radiation detected:**
  - Alpha > 7 MeV
  - Beta > 100 keV
  - Gamma > 7 keV
- **Accuracy: +/- 10% for Cs-137**

Proportional Counter

- Gas amplification occurs
- Charges collected are proportional to incident energy
- Can differentiate between radiation types
- RF is difficult to shield



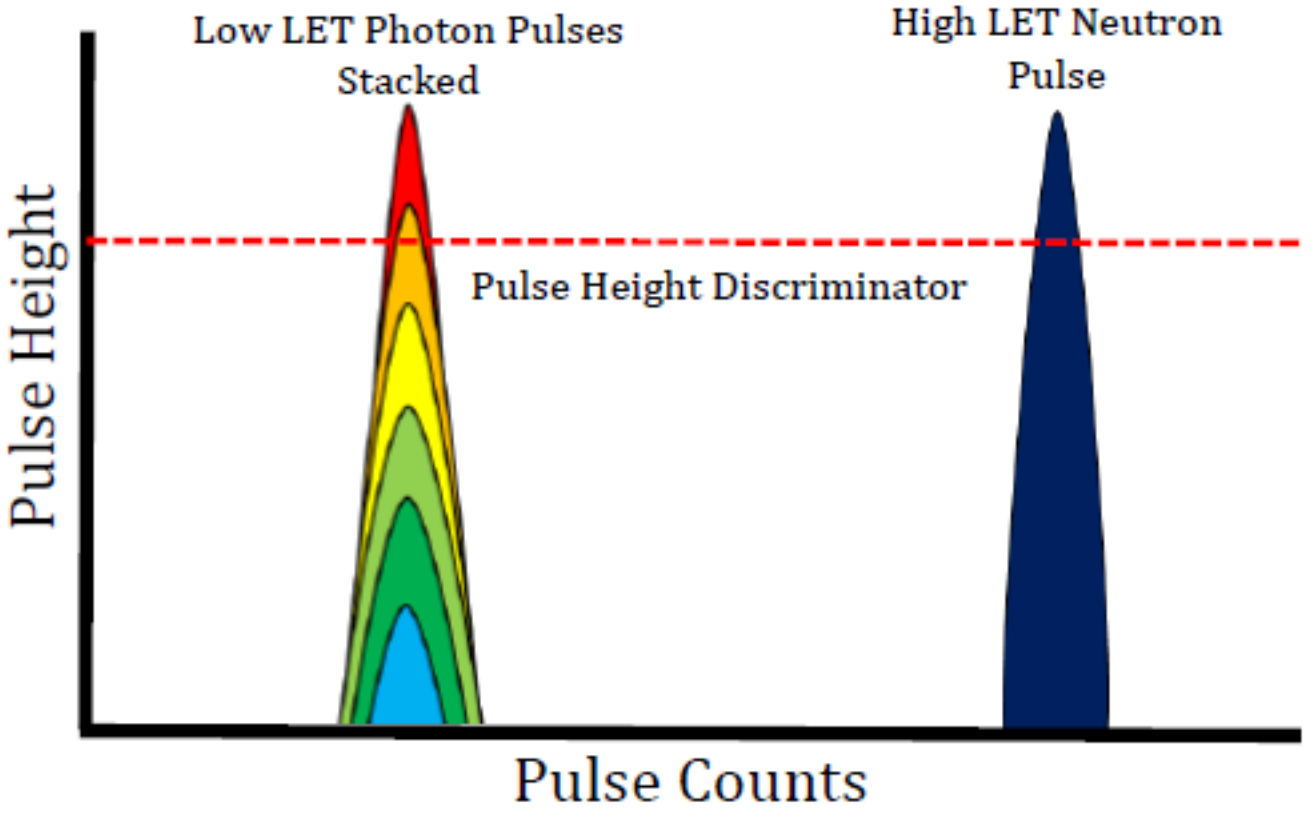
Proportional Counter (cont'd)

- Neutrons don't interact readily with all gases
- ^{3}He

$$ {}^{3}_{2}He + {}^{1}_{0}n \rightarrow {}^{3}_{1}H + {}^{1}_{1}p $$

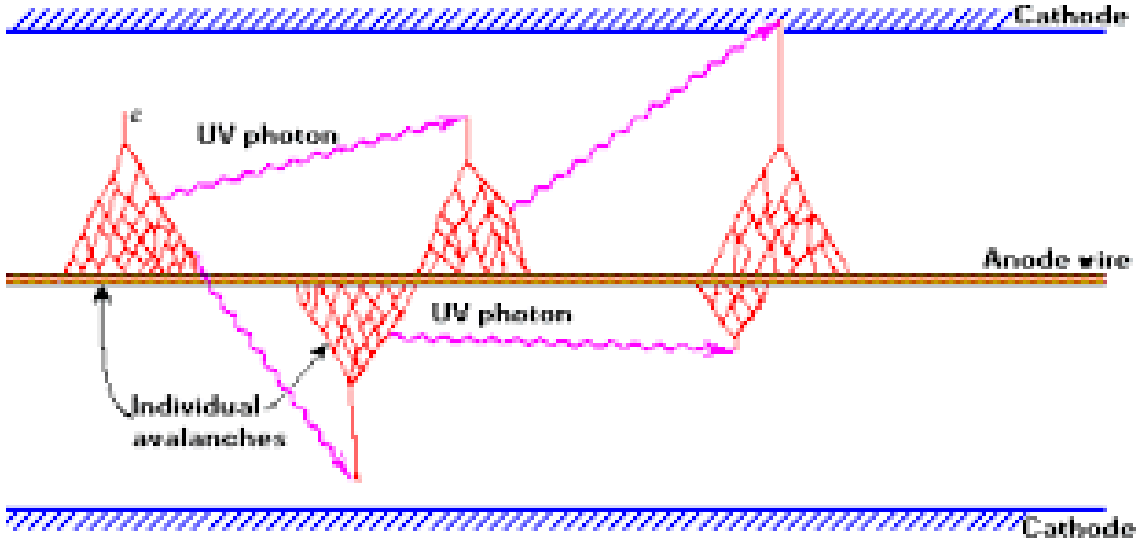
- **Advantages**: High efficiency, ruggedness
- **Disadvantages**: DOT shipping issues, RF and gamma interference

Proportional Counter (cont'd)



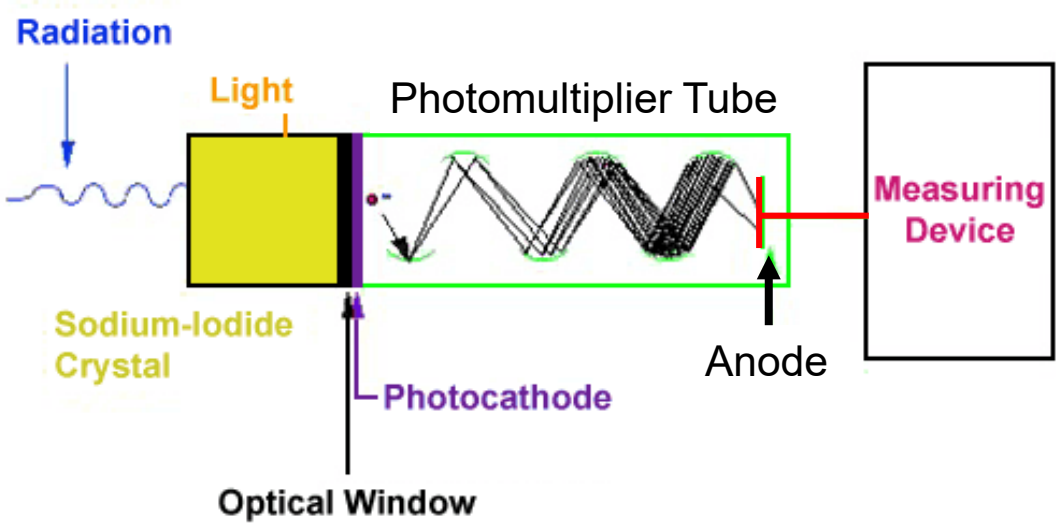
Geiger-Mueller Tube

- Geiger discharge



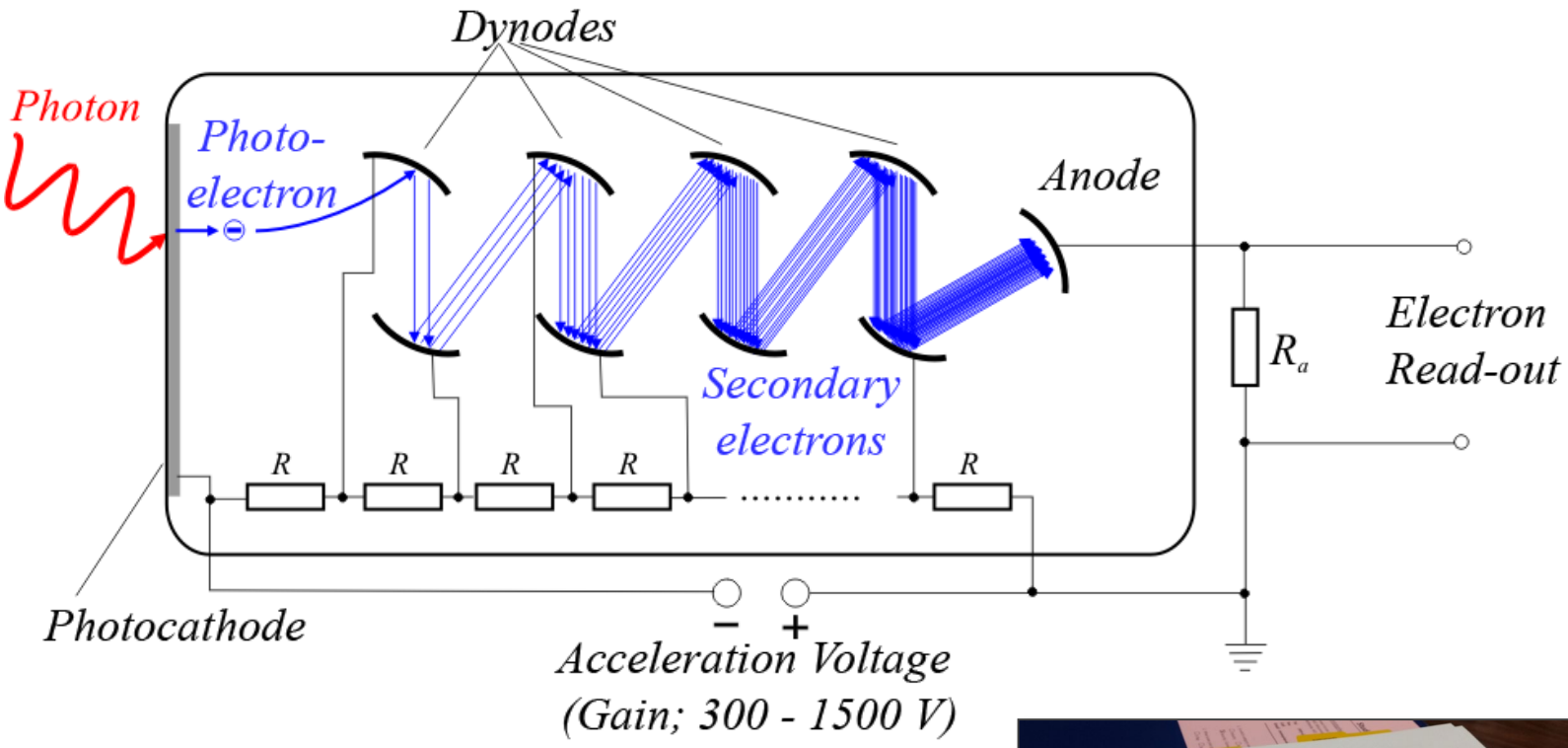
- Very high dead time
- Can paralyze in high radiation fields
- Primarily used for dosimetry applications

Scintillators



- **Ideal scintillation material characteristics**
  - High light output
  - Short decay time
  - Ability to be manufactured into usable sizes

Photomultiplier Tube



Photomultiplier Tube

- **Advantages**: Large area, good noise characteristics
- **Disadvantages:** Ruggedness issues

CsI (Tl) vs NaI (Tl)

- **CsI (Tl)**
  - High light output, long decay time
  - Expensive
  - Slightly hygroscopic
  - 8% energy resolution
- **NaI (Tl)**
  - High light output, short decay time
  - Inexpensive
  - Hygroscopic
  - 7% energy resolution

HRM

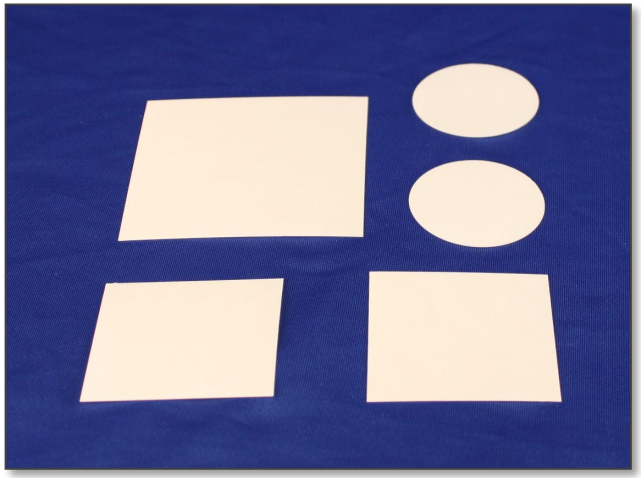
- **CsI Scintillator and He-3 Proportional Counter**
- **Dose rate range**
  - Standard: 0-120 µSv/hr
  - High Range: 120 µSv/hr-880 mSv/hr
- **Radiation detected**
  - Neutrons
  - Gamma > 45 keV

IdentiFINDER

- **Scintillator, He-3 Proportional Counter, and GM tube for higher dose rates**
- **Dose rate range**
  - Scintillator: 0-250 µSv/hr
  - GM Tube: 0-10 mSv/hr
- **Radiation detected**
  - Neutrons
  - Gamma: 20 keV-3 MeV (claimed)

ZnS (Ag)

- **Used for alpha detection**
- **Very low light conversion efficiency for fast electrons**
- **Opaque crystalline powder**
  - Limits use to thin screens

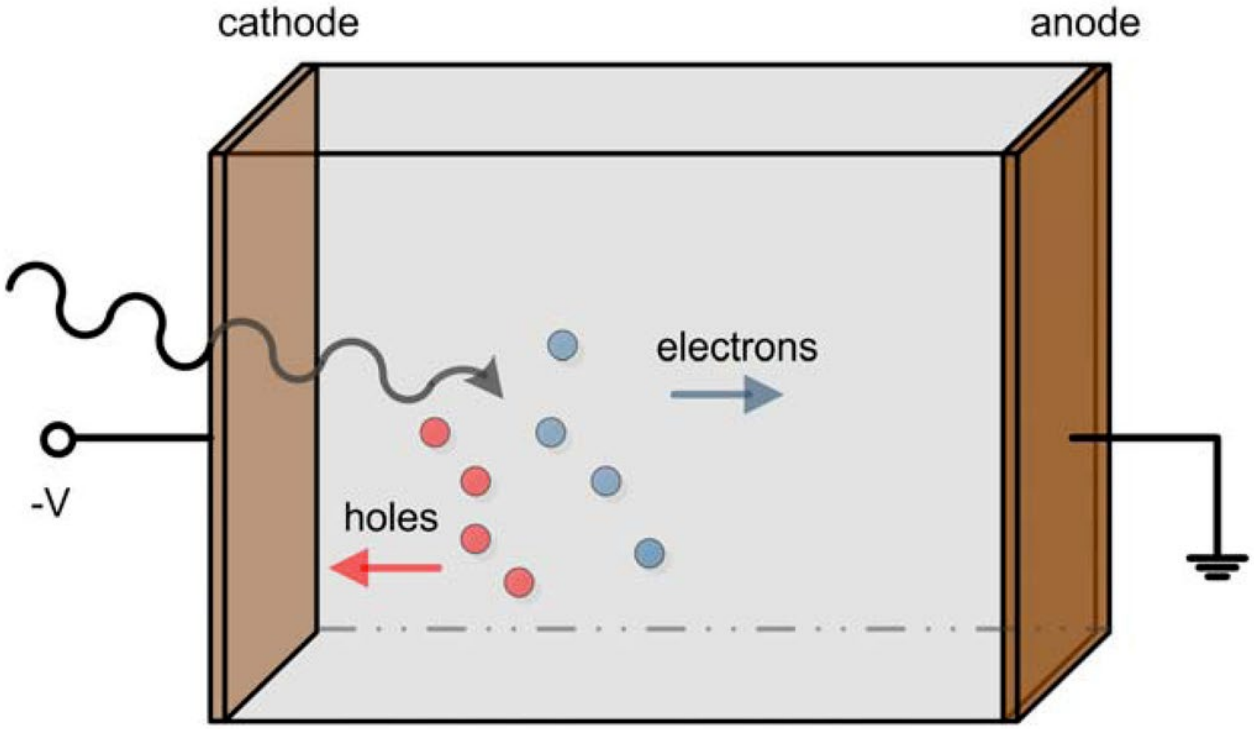


FH-40 Alpha/Beta Probe

- **Efficiency**
  - Alpha (Am-241): 36%
  - Beta (Co-60): 23%
  - Beta (Sr-90): 49%

Semiconductors

- **Require much less energy to produce charge carriers than scintillators**
  - ~3 eV vs ~33 eV



HPGe

- **Great energy resolution**
- **Must be cooled**
  - Liquid Nitrogen or mechanically cooled
  - Adds size and weight
  - Can be allowed to warm to room temperature between uses

ORTEC Detective

- **HPGe, He-3 Proportional Counter, GM tube**
- **Dose Rate Range**
  - HPGe: 0-20 µSv/hr
  - GM Tube: 0-10 Sv/hr
- **Radiation Detected**
  - Neutron
  - Gamma

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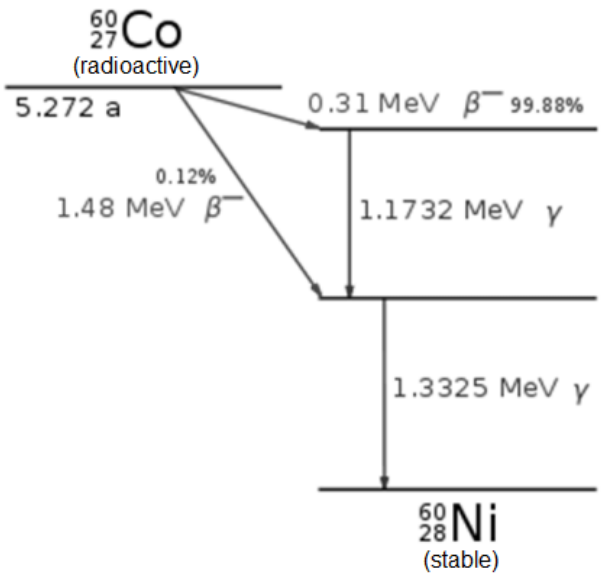
Isotope Identification

- **Each isotope has a “finger print” of emissions**
- **Exceptions**
  - Pure Beta Emitters
  - Positron Emitters
  - Neutron Emitters
- **Solid state detectors build a spectrum as they collect**

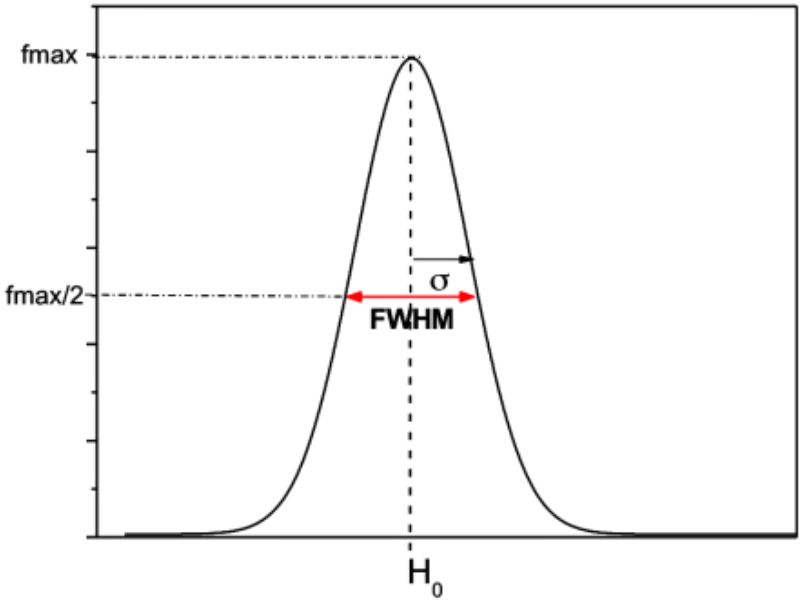


Spectrum Collection

1. An interaction occurs in the detector head
2. That interaction is converted into a pulse proportional to the energy
3. The Multi Channel Analyzer bins this information
4. Peaks are forms for analysis

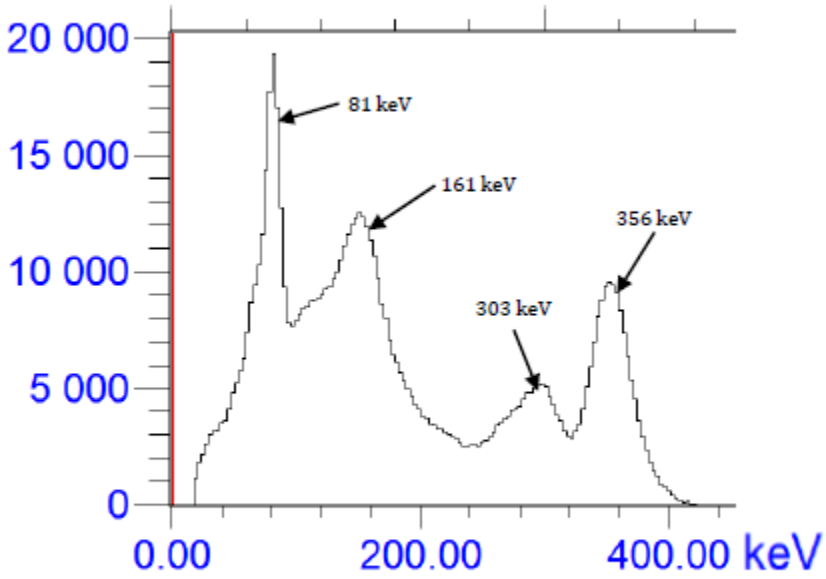
Energy Resolution

- Measure of energy peaks
- Full-width at half-maximum
- Peaks must be at least 1 FWHM apart to distinguish

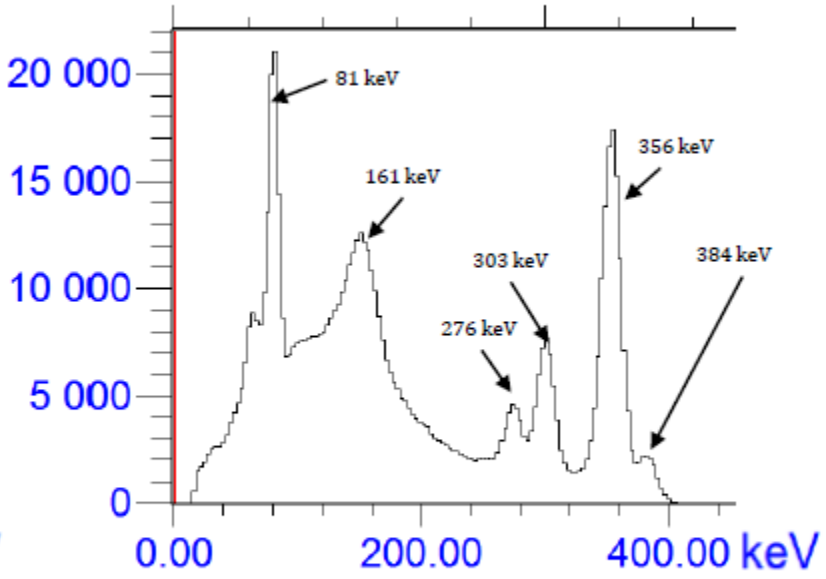


Energy Resolution (cont'd)

- Comparison between NaI and $LaBr_3$



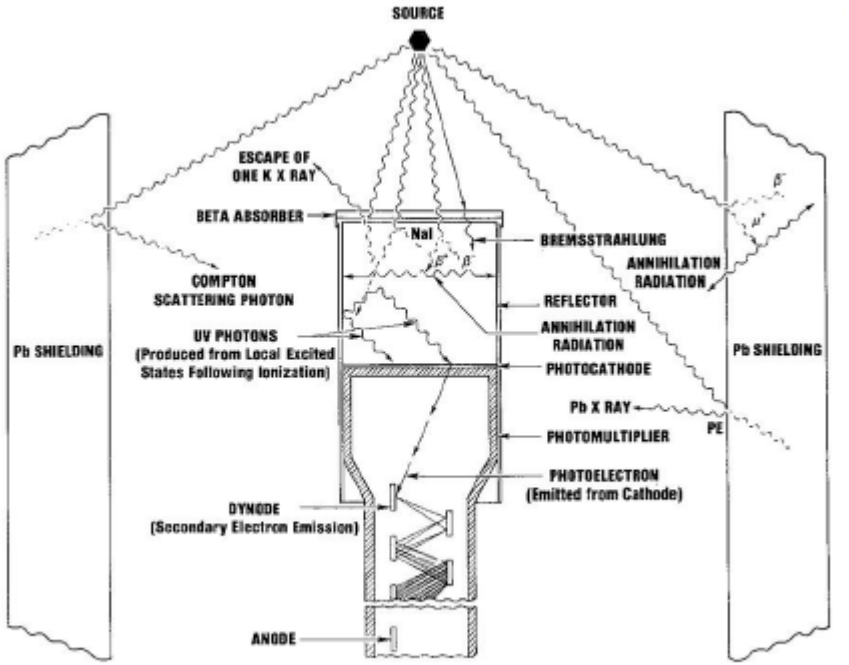
NaI(Tl) at ~7% resolution

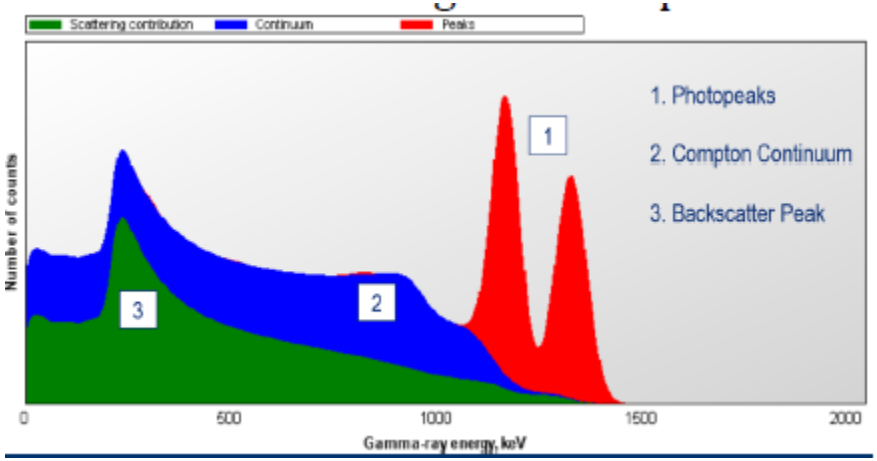


$LaBr_3$(Ce) at ~3% resolution

Spectrum Noise

- Interactions with surrounding materials and the detection medium create noise





Lesson Summary

- Four Detector Types: Ion Chamber, Proportional Counter, Scintillator, Semiconductor
- Know your instrument
  - Range
  - Advantages
  - Limitations
- Isotope Identification
  - Resolution
  - Spectrum features

Questions?